RESEARCH HIGHLIGHT

December 2009 Technical Series 09-112

Sloping Sand Filters for On-Site Wastewater Treatment

INTRODUCTION

Approximately 50% of Nova Scotia residents utilize on-site septic systems for wastewater treatment and disposal, however conventional treatment systems may be at greater risk of premature failure due to geologic conditions commonly found in the province, such as low permeability soils, shallow bedrock, and high water tables. To address these issues, sloping sand filters (SSF), or lateral flow sand filters (LFSF) as presented in figure 1.1, have been approved for use as remedial technology to replace failed conventional systems. While laboratory studies have indicated satisfactory performance very little field analysis has been undertaken.

PROJECT OBJECTIVES

This report presents findings from a two-year study examining the hydraulics and treatment performance of sloping sand filters (SSF), or lateral flow sand filters (LFSF), for on-site residential wastewater treatment. This study utilized, and expanded upon, an existing set of field scale SSFs that were installed at the Bio-environmental Engineering Centre (BEEC) in Truro, NS for experimental purposes. The overall objective of this research project was to assess current design guidelines for SSFs, and make recommendations for the expanded use, and optimization, of these types of systems. Specific objectives included: (i) assessing the hydraulic behaviour and performance of conventionally designed SSFs at loading rates greater than those allowed within NS technical guidelines, (ii) assessing the hydraulic behaviour and performance of SSFs that were

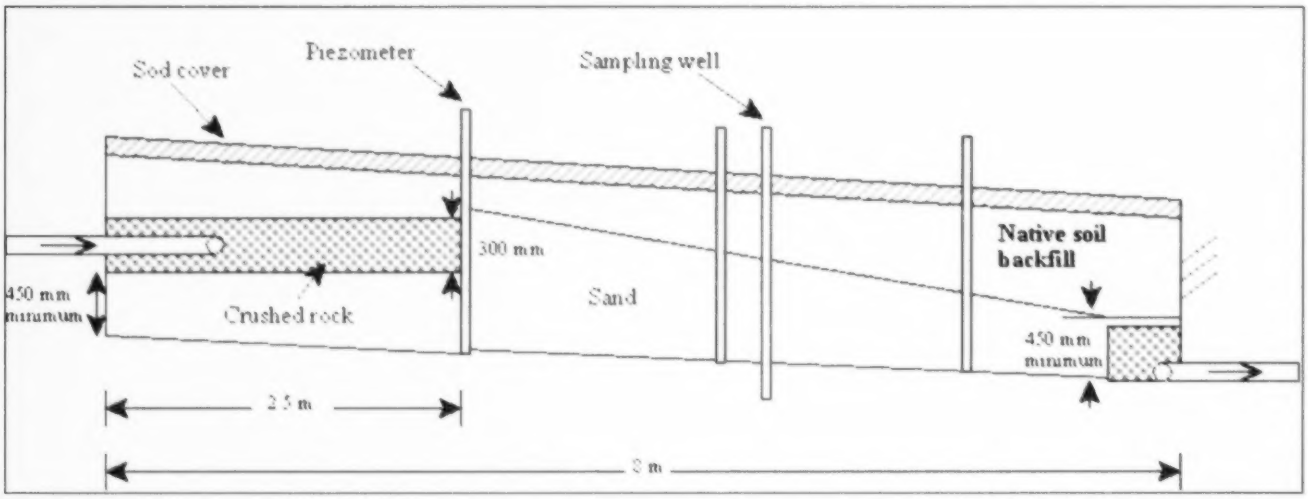

Figure 1 Schematic of a typical Lateral Flow Sand Filter used in Nova Scotia.

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substantially shorter than those required within NS technical guidelines, (iii) determining if current hydraulic models of SSF systems are appropriate.

METHODOLOGY

A total of eight pilot-scale SSF systems were installed at the BEEC, and continuously dosed with septic tank effluent. Filter construction encompassed the full range of sand sizes and slopes allowed within NS technical guidelines. Six of the SSFs were constructed according to NS technical guidelines but loaded at approximately double the recommended linear loading rate. Two replicate SSFs were constructed with downgradient lengths that were 50% of the length recommended in the NS technical guidelines, but were loaded according to the recommended linear loading rates. The hydrology and treatment performance of the systems were monitored over a 16-20 month period. A series of tracer studies were conducted within all eight filters over the course of the study. Tracer study data was fit to analytical residence time distribution models to assess the hydraulic functioning of the filters. Measured hydraulic characteristics were then compared to those predicted using theoretical models of porous media flow.

KEY FINDINGS

- External hydrologic factors can have a large influence on the flow characteristics of SSF systems. Outflows from the SSFs varied greatly, increasing by a factor of 4 during some precipitation events. However, the influence of precipitation on SSF hydrology is complex, and a strong function of antecedent moisture conditions.
- Observations from piezometers installed at several locations within each filter indicated that the filters were not fully saturated, even after the wastewater loading rate was increased.
- Observations from monitoring wells installed in the distribution trench of each filter indicated that the biomat within each filter was stable. Minor increases in ponding depths were observed in the distribution trench after wastewater loading rates were increased.
- In general, sand grain size had the greatest influence on residence time characteristics, as opposed to slope and wastewater loading rate. As expected, the fine grained filters have higher residence times compared to medium- and coarse-grained filters, presumably due to the smaller pore space for the wastewater to travel through. Residence times from medium and coarse grained filters were comparable.
- Tracer studies indicated that the residence time characteristics of the filters did not change after the wastewater loading rate was increased. This provided further evidence that biomat hydraulics have a large influence on the speed of wastewater movement through the filters.
- Comparison of measured mean residence times to theoretical residence times computed assuming saturated flow confirmed that saturated Darcy flow did not occur within the SSFs.
- In general the SSFs performed well over the monitoring period, producing average effluent five-day biochemical oxygen demand (BOD_5) concentrations below 10 mg/L, and average total suspended solids (TSS) concentrations below 15 mg/L.
- Median outlet *E. coli* levels were all below 10 CFU / 100 mL, indicating that the sand filters were generally effective at removing enteric bacteria. However, on several occasions levels of *E. coli* in filter effluent exceeded 100 CFU / 100 mL, illustrating variability in treatment performance. This indicated that effluent from SSF systems could not be surface discharged without additional disinfection.
- SSFs that were loaded at elevated rates, as compared to NS technical guidelines, performed well, providing a level of treatment that was similar to that observed at conventional loading rates.

- The shortened filters performed at the same level as a regular length filter under similar loading rate conditions. These results suggest that the majority of treatment occurs within the first part of the LFSF, and that treatment processes occurring within the biomat control the treatment efficiency of the system.
- Removal of Total Nitrogen (TN) was not affected by the increase in wastewater loading rate. The SSFs consistently removed between 40 – 50% of TN.
- A progressive reduction in phosphorus (P) removal was observed in each filter. After 3 years of effluent loading, several of the original six filters appear to be saturated with P. As expected, the coarse-grained filters saturate more quickly than fine-grained filters, as they would possess less surface area for adsorption. These results indicate that conventional sand-based disposal systems have virtually no long-term phosphorus removal capacity.

IMPLICATIONS FOR THE HOUSING INDUSTRY

This study has shown that current design loading rates for SSFs in NS are conservative, and provide an inherent safety factor. The SSF system was shown to be a reliable, relatively robust treatment system. However, sand-based systems such as these indicate variable *E. coli* removal and poor long-term phosphorous removal. Accordingly, consideration should be given to additional treatment and disinfection when utilized for surface discharge or for discharge into sensitive receiving bodies.

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